Interplay of soft and hard processes and hadron p_T spectra in pA and AA collisions *

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Hadron yields, spectra and correlations have been the focus of many experiments in relativistic heavy-ion collisions. They provide a snapshot of the state of matter when hadrons stopped interacting with each other, a stage often referred to as freeze-out in heavy-ion collisions. One can then infer the condition in the early stage prior to the freeze-out. Such a procedure relies crucially on our understanding of the dynamical evolution of the system. On the other hand, knowledge of the initial condition at the beginning of thermalization will also help one to unravel the history of evolution. This is especially the case when a complete thermalization cannot be achieved in certain regions of phase space (large p_T, for example). Therefore, it is important to study the hadron spectra in $p+p$ and $p+A$ collisions that will help us to understand the initial condition of the dense matter in high-energy heavy-ion collisions.

In this paper we have proposed to analyze the hadron transverse momentum spectra in terms of the nuclear modification factor $R_{AB}(p_T)$ which is defined in such a way that a naive additive model of incoherent hard parton scattering would give $R_{AB}=1$. We demonstrated in a schematic model of Glauber multiple parton scattering that the modification factor $R_{AB}(p_T)$ has a nontrivial p_T dependence due to the absorptive processes and the interplay between soft and hard parton scattering, excluding final state scatterings. Because of the absorptive processes, the hadron production at small $p_T \sim 0$ is coherent and the hadron spectra in AB collisions are proportional to the number of participant nucleons, leading to $R_{AB}<1$. At large p_T the hard parton scatterings become incoherent. Multiple parton scatterings then enhance the hadron spectra so that $R_{AB}>1$. The momentum scale p_0 at which the transition occurs $[R_{AB}(p_0)=1]$ can be identified as the scale that separates soft and hard processes underlying both pp and AB collisions. Analyses of the existing experimental data on pp, pA and AB collisions indicate that $p_0 \approx 1-2$ GeV$/c$.

We pointed out that such analyses of future experimental data are important to study the effect of final state interactions. At low p_T, collective radial flow from hydrodynamic expansion gives similar p_T dependence of R_{AB}. Disentangling the effects of initial multiple scattering and the radial flow would require a careful study of the modification factor in pA collisions, especially its dependence on the hadron mass. At large p_T, parton energy loss will lead to suppression of the hadron spectra. Experimental measurement of R_{AB} will provide important information on the initial parton density that is produced in heavy-ion collisions. At the intermediate p_T, we have shown that the p_T dependence of R_{AB} is sensitive to the energy dependence of dE/dx. This in turn is related to gluon absorption by the propagating partons reflecting the detailed balance in an equilibrating system.

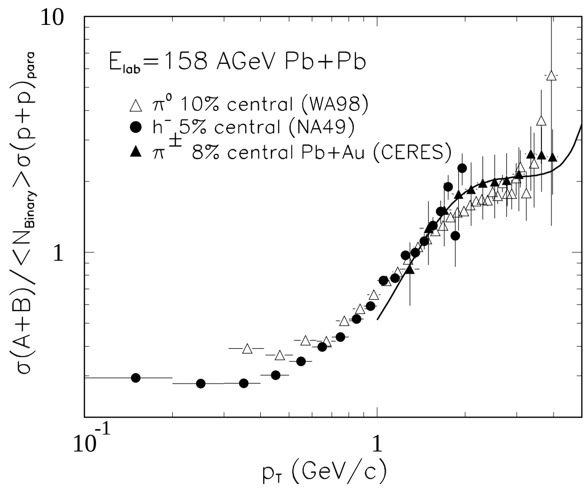

Figure 1: The nuclear modification factor $R_{AB}(p_T)$ for hadrons in AB collisions at $E_{\rm lab}=158$ GeV. The line is the pQCD parton model calculaiton.

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